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(71) Applicant: W.R. GRACE & CO.
Grace Plaza 1114 Avenue of the Americas
New York New York 10036(US)

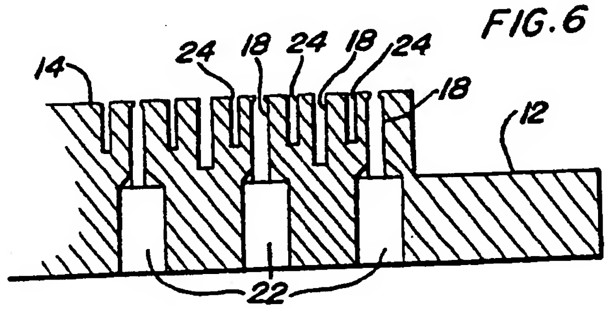
(72) Inventor: Lundsager, Christian Bent
1308 Patuxent Drive
Ashton Maryland 20861(US)

(74) Representative: UEXKÜLL & STOLBERG
Patentanwälte
Beselerstrasse 4
D-2000 Hamburg 52(DE)

(54) **Die and processes.**

(57) Forming thin-wall honeycomb structures using novel extrusion die (10); method of making the die (10). The die has feed holes (22) feeding to slots (18) of a primary extrusion grid. A secondary grid is milled between slots of the primary grid (18), and successive subsequent grids (24) can be provided between previously milled slots (secondary grid, tertiary grid, quarternary grid), and so on. Extrudable material is fed to the die under pressure; the material flows through the feed holes longitudinally to the primary grid (18), whence the material flows to subsequent grid (24) or grids. The material emerges from the die face as a thin-walled honeycomb structure. It is then rigidified to prevent deformation.

FIG.6



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die. Slots of a secondary grid 24 have been milled and centered between the slots of the primary grid 18. The secondary slots are not as deep in the die face 14 as those of primary grid 18 and do not directly contact or communicate with feed holes 22. Secondary grid 24 can receive extruder feed only from primary grid 18. In the sectional view shown in Fig. 6 all of the slots of the same number should be considered as having the same width and all of the slots 18 extend down to the same depth which is a depth lower than the depth to which the slots 24 extend.

The actual milled width of the slots of both the primary grid 18 and the secondary grid 24 may be larger internally than at the die face 14. As noted elsewhere in the description, uniformity of aperture width of both grids can be achieved by electroplating the die face 14, including all grid slots, followed by remilling to the narrower aperture dimensions.

Preparation and Operation of the Die

In this particular case a die blank is chosen to fit a conventional extruder having a 2 ⅝ inch internal diameter, with an annular retainer flange to hold the die. The blank is 3 ½ inches in diameter, ⅝ inches thick, of tool die steel. On one face to be referred to as the outlet face a peripheral recess 12, ¼ inch deep is turned, leaving a raised face 14, 2 ½ inches in diameter. Slots 18 are milled into the outlet face in two perpendicular directions, five per inch, 1/32 inch wide, ¼ inch deep, symmetric on 2 ½ inch diameter. Pilot holes 16 having 1/32 inch diameter are drilled from the outlet face side, through the blank and staggered at alternate slot crossings. Preferably, holes are avoided closer than 3/32 inches from the face perimeter. The result of these operations is seen in Fig. 1, a plan view looking down on the die outlet face.

Continuing, ⅛ inch holes 22 are drilled from the opposite inlet side (the pressure side), to ⅜ inches deep, and all burrs between slots and holes are cleaned. The result is seen in Fig. 3.

Next, the slotted face only (not the pressure face) is chrome-plated. In this operation the slots are not electroplated all the way down, just part way, so as to partially close the slots, to less than 0.015 inch opening. The chrome is then ground off the face, but leaving it in the slots. The slots are remilled, centered to 0.014 inch aperture width. For this operation (and the next) a diamond saw is recommended, since the cuts are at least partially in chrome.

The next step is a majot aspect of the invention. In this operation, new slots 24 are milled, centered between existing slots 18, to 3/16 inch deep, 0.014 inches wide, and burrs are cleaned. The results are seen in Figs. 5 and 6. From a simple visual inspection of the face of the die (Fig. 5) it cannot be determined which are the first milled deep slots (primary grid) 18 and which are the second milled shallow slots (secondary grid) 24, since the slot apertures are all the same width (0.014 inch in this case). This uniformity of aperture provides uniformity of wall thickness in the extruded honeycomb structure.

To operate the die, the extruder mix is forced under pressure into the longitudinal feed holes 22. These feed to the slots of the primary grid 18, which in turn feed to the die face and also to the secondary grid 24. The flow through the feed holes 22 will meet increased resistance to the flow as it enters into the slots 18 of the primary grid, and will flow towards the discharge of those slots, as well as laterally to fill not only the primary slots between the feed holes 22 but also the secondary slots, which are interconnected with the primary slots and with each other. The product emerging is a thin-walled honeycomb structure, without differentiation as to source of the mix (i.e., whether from the primary or the secondary grid).

Thus, going across, and having regard to successive grids, each secondary slot is milled between two primary slots. When there is a tertiary grid each tertiary slot is milled between a secondary slot and a primary slot and then between that secondary slot and the next primary slot. When there is a quaternary grid, the quaternary slots are milled between primary and tertiary, then between a tertiary and secondary, then between a secondary and tertiary, and finally between a tertiary and primary; after which the pattern repeats.

From the foregoing it will be evident that additional grids may be superimposed on the die face of Fig. 5, viz. a tertiary grid, centered between the slots of the previously machined grids and shallower and optionally narrower than the slots of the said grids; a quaternary grid, milled as above described, and so on. The slots of each successive grid are suitably shallower and narrower than those of the preceding grid, and material is added to the previous slots to allow remachining of those slots to a narrower aperture to match the aperture of all slots. There is no direct communication of the feeder holes with any of these secondary and subsequent grids. They are fed by flow from the deeper-seated preceding grids; i.e., primary to secondary, primary and secondary to tertiary, and so on. The primary grid 18 is fed exclusively by the feeder holes 20. If the tertiary slots are narrower, say 7 mil, the cutting of these slots is preceded by electroplating of the face and the primary and secondary slots, grinding of the face and recutting of primary and secondary slots to the same width

support than dies of the prior art, and is stronger than prior art dies by reason of this internal support. The support and strength is provided without unreasonable reduction of flow, and it is able to do this because of the novel die design. As to this design, one of the improvements has been to provide bigger but fewer feed holes. This makes for faster flow (less pressure) for the same cross-sectional volume. Approximately the same amount of metal is removed from the die as in prior art dies, but the resulting internal configuration is greatly different. As the feed holes contact the primary grid, and these latter contact the subsequent grid or grids, this condition of greater flow channels continues, cross-section by cross-section, as one examines the die longitudinally, proceeding from the feed side toward the extrusion face 14. And yet at the extrusion face, the plural grids (18, 24, etc.) provide the same volume of extruded honeycomb at lower pressures, and more volume in terms of higher linear speed at higher pressures, compared with prior art dies.

The die of this invention is particularly suitable in extruding ceramic mixes, such as the one described in U. S. 3,790,654, one having typically the following composition:
58 parts by weight of pulverized EPK Florida Kaolin, obtainable from Whittaker, Clark and Daniels of New York, N.Y.; about 20 parts by weight of Texas white talc #2619, obtainable from Hammel & Gillespie, Inc. of White Plainfield, N.J.; about 22 parts by weight of T-61 alumina produced by Aluminum Corp. of America, and about 28 parts by weight of water. Suitable bonding and plasticizing aids are included, such as methyl cellulose.

The above mix is suitably fed to the die of this invention at a pressure of 400 psi and at an extrusion rate of about 60 inches per minute. In operation, the mix flows through the feed holes 22, thence into the slots of the primary gridwork 18, thence into the slots of the secondary gridwork 24. The mix is extruded as a honeycomb structure from the aggregate of grids 18 and 24. The resulting structure has 100 openings per square inch, with wall members therebetween of about 0.014 inches, thus producing an open frontal area of about 75%. The honeycomb structure rigidifies by drying, after which it is fired, and the walls are then found to be even thinner.

In other words, the method of forming a honeycomb structure in accord with this invention comprises flowing an extrudable material longitudinally through a plurality of feed passageways, delivering such flow of material from said feed passageways directly to intersecting portions of a primary grid of interconnected discharge slots having exit apertures of substantially uniform width, delivering a portion of the flow in the primary grid laterally to a secondary grid of interconnected discharge slots having exit apertures of substantially the same width as those of the primary grid, the slots of the secondary grid receiving extrudable material only from the slots of the primary grid, and longitudinally discharging said material from the aggregate of said slots to form a continuous thin walled honeycomb mass. Variations and refinements include one or more additional grids (e.g., tertiary, quaternary, and so on), and rigidifying the extruded honeycomb structure, e.g., by drying, firing, etc.

The method of making a honeycomb structure in accordance with this invention may also be defined and described as an improvement over prior art methods, to wit, in the method of forming a honeycomb structure from an extrudable material comprising flowing an extrudable material longitudinally through a plurality of feed passageways, delivering such flow of material from said feed passageways directly to intersecting portions of a primary grid of interconnected discharge slots having exit apertures of substantially uniform width, longitudinally discharging said material to form a continuous thin-walled honeycomb mass and rigidfying said mass to provide a rigid structure having a plurality of passages extending therethrough separated by thin walls, the improvement comprising delivering a portion of the flow of material from the primary grid to a secondary grid of interconnected discharge slots having exit apertures of substantially the same width as those of the primary grid; the slots of the secondary grid receiving extrudable material from the slots of the primary grid.

Variations

The die as shown in the figures is circular and is designed to fit conventional extruders, with suitable retainer cups and/or rings. However, the die face 14 may be made substantially any shape: elliptical, polygonal, etc., while still utilizing the features of the invention.

Specific feed hole sizes and grid widths and depths are given in the description. These dimensions are subject to considerable variation, while still working within the invention, as will be obvious to those skilled in the art.

As disclosed, milling of the slots of grids 18 and 24 is done with a saw. This is a conventional machining operation. The slots can also be cut by other routing machine shop procedures, including electric discharge machining and chemical machining. if desired, the slots may be prepared in various subsurface contours, e.g., they may be undercut, typically by electrical discharge machining; or a

a) flowing an extrudable material longitudinally through a plurality of feed passageways

b) delivering such flow of material from said feed passageways directly to portions of a primary grid of interconnected discharge slots having exit apertures of substantially uniform width.

c) delivering a portion of the flow of the primary grid to a secondary grid of interconnected discharge slots having exit apertures of substantially the same width as those of the primary grid, the slots of the secondary grid receiving extrudable material only from the slots of the primary grid, and

d) longitudinally discharging said material from the aggregate of said slots to form a continuous thin walled honeycomb mass.

10. Method according to Claim 9 in which the feed passageways in step a) are circular in cross-section.

11. Method according to Claim 9 in which at least a portion of the flow from the primary and secondary grids in step c) is delivered to at least one additional grid, whereby said additional grid receives extrudable material from the slots of the primary and secondary grids.

12. Method according to Claim 9 wherein following discharge in step d), the extruded honeycomb mass is rigidified to provide a rigid structure have a plurality of passages extending therethrough separated by thin walls.

13. In the method of forming a honeycomb structure fron an extrudable material comprising flowing an extrudable material longitudinally through a plurality of feed passageways, delivering such flow of material from said feed passageways directly to intersecting portions of a primary grid of interconnected discharge slots having exit apertures of substantially uniform width, longitudinally discharging said material to form a continuous thin-walled honeycomb mass and rigidfying said mass to provide a rigid structure having a plurality of passages extending therethrough separated by thin walls

the improvement comprising delivering a portion of the flow of material from the primary grid to a secondary grid of interconnected discharge slots having exit apertures of substantially the same width as those of the primary grid; the slots of the secondary grid receiving extrudable material only from the slots of the primary grid.

14. The method according to Claim 13 in which a portion of the flow of material from the secondary grid is delivered to at least one addition grid of interconnected discharge slots having exit apertures of substantially the same width of those of the primary and secondary grids.

15. Method of making a die for the extrusion of thin-wall honeycomb structures, comprising the steps,

a) forming a die blank;

b) milling a primary grid of intersecting slots into one face of the die blank, said face to be the extrusion face;

c) drilling pilot holes through the die blank to communicate with slots of the said grid;

d) drilling feed holes through the pilot holes from the opposite side to contact the grid intersections;

e) depositing metal on the extrusion face and in the slots of the primary grid so as to at least partially close said slots;

f) re-milling the slots of the primary grid to a narrower dimension; and

g) milling new slots between the slots of the primary grid so as to provide a secondary grid, said new slots being shallower than the slots of the primary grid and of substantially the same width and communicating only with the slots of the primary grid.

16. Method according to Claim 15, comprising the further step

h) milling at least one additional set of slots into the die face, said additional set of slots (herein referenced as tertiary grid) being shallower than the slots of the preceding secondary grid in step (g) and communicating with the slots of all preceding grids.

17. Method accroding to Claim 16, in which, following step h) which produced the tertiary grid, new slots are milled between the slots of the primary, secondary and tertiary grids, said new slots (herein referenced as quarternary grid) being shallower than the slots of the tertiary grid, and communicating with the slots of the primary, secondary and tertiary grids.

18. Method according to Claim 15, in which the metal deposition is chrome plating.

19. Method according to Claim 15, in which the extrusion face of the die is ground to flatness following at least the final deposition of metal.

FIG. 4

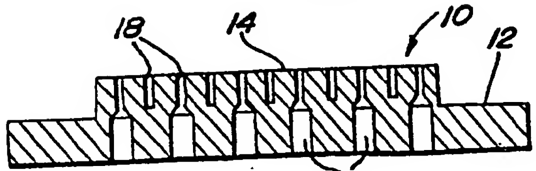

FIG. 4a

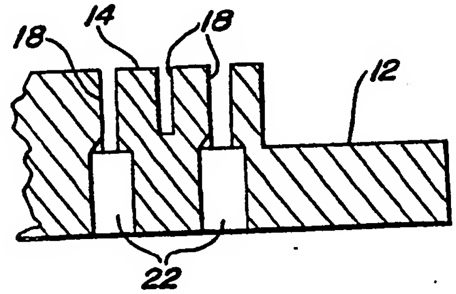

FIG. 5

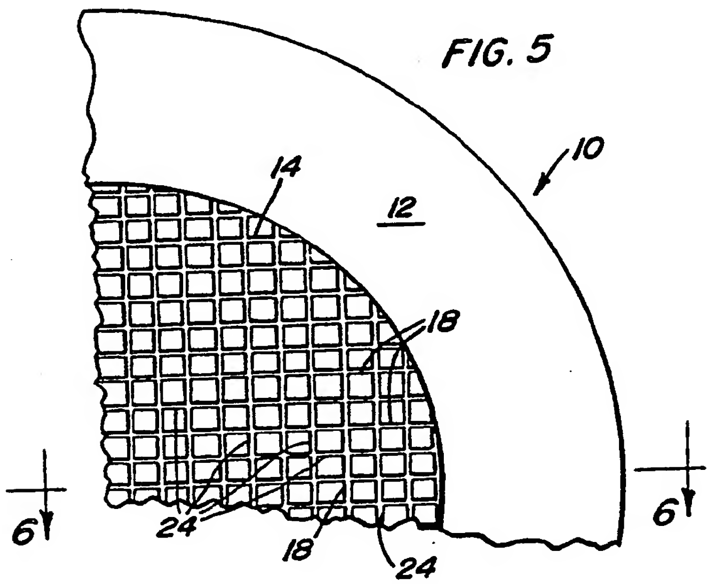

FIG. 4b

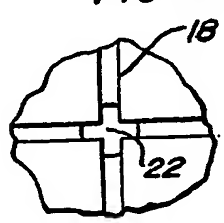

FIG. 4c

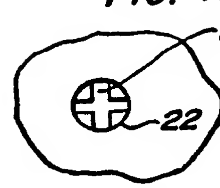

FIG. 6

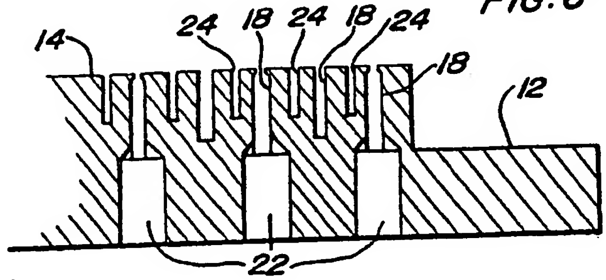

FIG. 4d